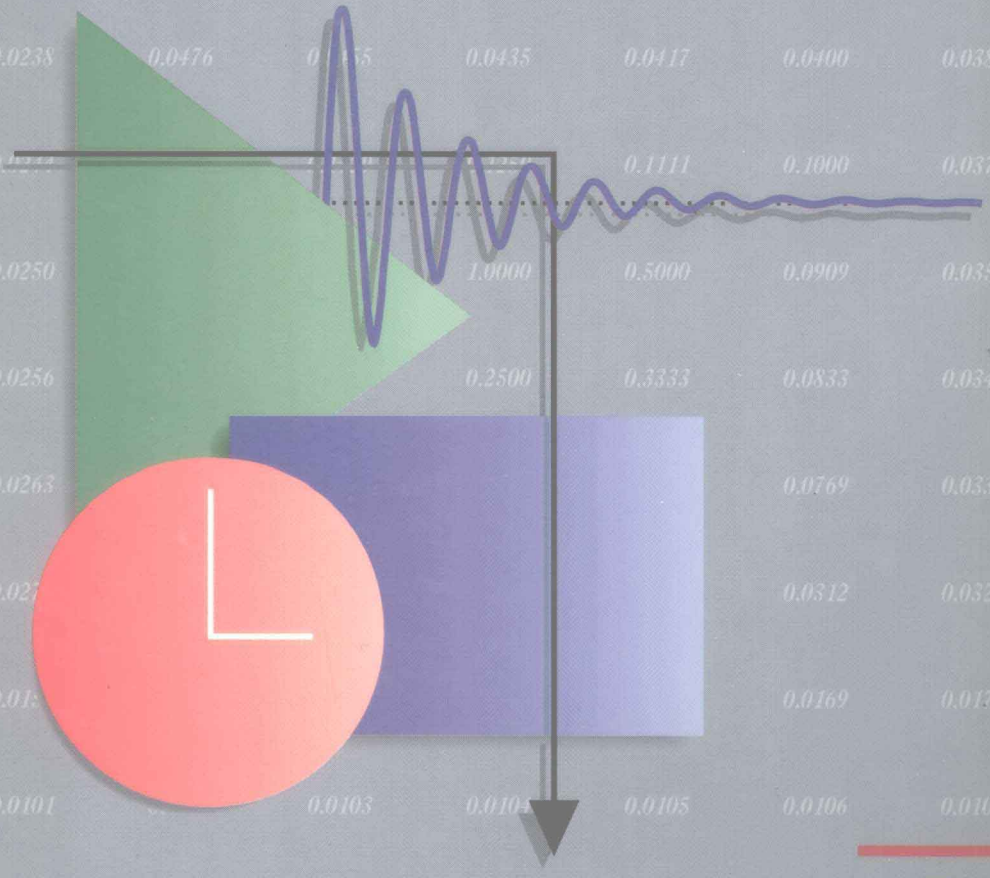
The Student Edition of SIMULINK®

Dynamic System Simulation Software for Technical Education



The MATH WORKS Inc.

User's Guide

The Student Edition of SIMULINK®

Dynamic System Simulation Software for Technical Education

User's Guide

The MATLAB® Curriculum Series

PRENTICE HALL, Englewood Cliffs, NJ 07632

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Preface

To the Instructor

SIMULINK® is a package for use with MATLAB® for modeling, simulating, and analyzing dynamical systems. Its graphical modeling environment uses familiar block diagrams, so systems illustrated in texts can be easily implemented in SIMULINK. The simulation is interactive, so you can change parameters and immediately see what happens. The analysis tools include those built into SIMULINK, plus the many tools in MATLAB and its application toolboxes. This combination of ease of use with flexible and powerful capability has already made SIMULINK the choice for thousands of engineers, instructors, and students in industry and academia.

Now, The Student Edition of SIMULINK, in combination with The Student Edition of MATLAB, gives students an affordable way to use this powerful modeling and simulation environment in their studies, while learning a tool that will prove invaluable throughout their careers.

SIMULINK allows students to move beyond idealized linear models, to explore more realistic nonlinear models that account for friction, air resistance, gear slippage, and other real-world phenomena. It turns the student's computer into a virtual laboratory for doing detailed analysis and understanding of systems that simply wouldn't be possible or practical otherwise. These systems might describe the response of an electric motor, the flight dynamics of an airplane, the active suspension system of a car, or the effect of the monetary supply on the economy. And it makes it fun.

The Student Edition of SIMULINK for the student's own personal computer is an excellent complement to educationally discounted licenses of the professional version, such as computer lab licenses or workstation site licenses. SIMULINK models are fully compatible, both between the student and profes-

sional versions and across computer platforms. As a result, students can take their models to the lab to use advanced tools like the code generation or real-time hardware support provided by the SIMULINK Real-Time Workshop.

By itself, or when coupled with texts, SIMULINK can be effectively incorporated into the curriculum to enhance students' modeling and analysis skills, plus understanding of system dynamics and behavior.

Technical Support for Instructors

The MathWorks provides technical support to registered instructors who use The Student Edition of SIMULINK in their courses.

For technical support questions, instructors can direct inquiries

- Via e-mail: `support@mathworks.com`
- Via telephone: (508) 653-1415 ext. 4300
- Via fax: (508) 653-2997

Other Information Sources for Instructors and Students

- Use the SIMULINK online help facility by typing `help simulink` at the MATLAB prompt.
- Students and instructors with access to Usenet newsgroups can participate in the `comp.soft-sys.matlab` newsgroup. Here, an active community of MATLAB and SIMULINK users – spanning industries, countries, applications, and schools – exchange ideas, help with each other's questions and problems, and share user-written functions and tools. Members of The MathWorks staff also participate, and the newsgroup has become a stimulating, open, and free-flowing forum.
- On the World Wide Web (WWW), use Mosaic or another browser to reach The MathWorks Home Page using the URL `http://www.mathworks.com`.
- The MathWorks maintains an electronic archive of user-contributed routines, product information, and other useful things. It can be reached using anonymous ftp to `ftp.mathworks.com`, or from the MATLAB Forum in the MathWorks Home Page on the WWW.
- The quarterly MathWorks newsletter *MATLAB News & Notes* provides information on new products, technical notes and tips, application articles, a calendar of trade shows and conferences, and other useful information. *MATLAB News & Notes* is free to registered users of The Student Edition of SIMULINK.

MATLAB-Based Books

A number of books can be used with the student editions of MATLAB and SIMULINK, many featuring exercises, problem sets, and supplemental functions. These include standard texts or supplemental workbooks in a broad range of courses, such as Control Theory, Signals and Systems, and Linear Systems.

For a current list of MATLAB-based books, consult the MathWorks Home Page on the WWW at `http://www.mathworks.com` in the MATLAB Forum or the MathWorks anonymous ftp server at `ftp.mathworks.com` in `pub/books/booklist`. Or contact your MathWorks educational account representative at (508) 653-1415 (e-mail: `info@mathworks.com`).

Acknowledgments

The Student Edition of SIMULINK is the product of a collaborative effort between The MathWorks and Prentice Hall, with many people contributing to its development. At The MathWorks, we especially want to acknowledge Rick Spada, Michael Cooperman, Andy Grace, Gary Levenson, Scott French, Luis Bascones, Anna Fiehler, Paul Carter, Donna Sullivan, Liz Callanan, Roy Lurie, and Jim Tung. At Prentice Hall, there have been contributions from Marcia Horton, Tom Robbins, Phyllis Morgan, Joe Scordato, Gary June, Amy Rosen, Paula Maylahn, Joe Sengotta, Donna Sullivan, Frank Nicolazzo, and Don Fowley.

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1 Getting Started

1.1 To the Student

Welcome to the Student Edition of SIMULINK! In the last few years, SIMULINK has become the most widely used software package for modeling and simulating dynamical systems in academia and industry. Now, The Student Edition of SIMULINK, in combination with The Student Edition of MATLAB, makes it practical for you to use this powerful environment on your own personal computer in your home, dorm, or wherever you study.

SIMULINK encourages you to try things out. You can easily build models from scratch, or take an existing model and add to it. Simulations are interactive, so you can change parameters "on the fly" and immediately see what happens. You have instant access to all of the analysis tools in MATLAB, so you can take the results and analyze and visualize them. We hope that you will get a sense of the *fun* of modeling and simulation, through an environment that encourages you to pose a question, model it, and see what happens.

With SIMULINK, you can move beyond idealized linear models to explore more realistic nonlinear models, factoring in friction, air resistance, gear slippage, hard stops, and the other things that describe real-world phenomena. It turns your computer into a lab for modeling and analyzing systems that simply wouldn't be possible or practical otherwise, whether the behavior of an automotive clutch system, the flutter of an airplane wing, the dynamics of a predator-prey model, or the effect of the monetary supply on the economy.

It is also practical. With thousands of engineers around the world using SIMULINK to model and solve real problems, knowledge of these tools will serve you well, not only in your studies but also throughout your professional career.

We hope you enjoy exploring the software.

1.1.1 What Is SIMULINK?

SIMULINK is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can be also multirate, i.e., have different parts that are sampled or updated at different rates.

For modeling, SIMULINK provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. With this interface, you can draw the models just as you would with pencil and paper (or as most textbooks depict them). This is a far cry from previous simulation packages that require you to formulate differential equations and difference equations in a language or program. SIMULINK includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. You can also customize and create your own blocks.

Models are hierarchical, so you can build models using both top-down and bottom-up approaches. You can view the system at a high-level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This provides insight into how a model is organized and how its parts interact.

After you define a model, you can simulate it, using a choice of integration methods, either from the SIMULINK menus or by entering commands in MATLAB's command window. The menus are particularly convenient for interactive work, while the command-line approach is very useful for running a batch of simulations (for example, if you are doing Monte Carlo simulations or want to sweep a parameter across a range of values). Using scopes and other display blocks, you can see the simulation results while the simulation is running. In addition, you can change parameters and immediately see what happens, for "what if" exploration. The simulation results can be put in the MATLAB workspace for postprocessing and visualization.

Model analysis tools include linearization and trimming tools, which can be accessed from the MATLAB command line, plus the many tools in MATLAB and its application toolboxes. And because MATLAB and SIMULINK are integrated, you can simulate, analyze, and revise your models in either environment at any point.

1.1.2 How to Use this Manual

Because SIMULINK is graphical and interactive, we encourage you to jump right in and try it.

The manual contains seven chapters and two appendices. Chapters 2 through 5 describe important topics, providing conceptual and procedural information as appropriate. Chapters 6 and 7 provide reference information.

For a useful introduction that will help you start using SIMULINK quickly, take a look at "Running a Demo Model" in Chapter 2. Browse around the model, double-click on blocks that look interesting, and you will quickly get a sense of how SIMULINK works. If you want a quick lesson in building a model, see "Building a Simple Model" in Chapter 2.

Chapter 3 describes in detail how to build and edit a model. It also discusses how to save and print a model and provides some useful tips.

Chapter 4 describes how SIMULINK performs a simulation. It covers simulation parameters and the integration methods used for simulation, including some of the strengths and weaknesses of each method that should help you choose the appropriate method for your problem. It also discusses multirate and hybrid systems.

Chapter 5 discusses methods for creating your own blocks and using masks to customize their appearance and use.

Chapter 6 provides reference information for all SIMULINK blocks (although blocks in the Extras library are described in Appendix B).

Chapter 7 provides reference information for the simulation and analysis tools supplied with SIMULINK.

Appendix A provides tables of summary information about all block libraries (except the Extras library) provided with SIMULINK.

Appendix B provides brief descriptions of blocks in the Extras library. These are more advanced or specialized blocks and are included for their usefulness.

Although we have tried to provide the most complete and up-to-date information in this manual, some information may have changed after it was printed. Please check the `README` file delivered with your SIMULINK system for the latest release notes.

1.1.3 Comparing The Student Edition of SIMULINK to Professional SIMULINK

The Student Edition is available for Windows compatible personal computers and Macintosh systems. It is identical to the SIMULINK 1.3 professional version except for the following:

- Requires The Student Edition of MATLAB version 4.
- Models are limited to 40 blocks. (Note that Subsystem blocks and Inport and Outport blocks are not included in this limitation, so there is no penalty for making your model hierarchical. Some SIMULINK blocks are compound mask blocks and contain more than one block.)
- Prints to Windows, Macintosh, and PostScript printing devices only.
- Available in single-user licenses only (no networking).
- S-functions (linked C code for blocks) are not supported.

The Student Edition of SIMULINK provides a Student User Upgrade Discount for purchase of the professional version (refer to the registration card for more information).

1.1.4 How to Upgrade to Professional SIMULINK

The professional versions of MATLAB and SIMULINK are available for MS-Windows and Macintosh personal computers; UNIX workstations from Sun, Hewlett-Packard, IBM, Silicon Graphics, and Digital; and VMS computers. For product information or to place an order, call or write your educational account representative at The MathWorks at:

The MathWorks, Inc.
University Sales Department
24 Prime Park Way
Natick, Massachusetts 01760-1500
Phone: (508) 653-1415
Fax: (508) 653-2997
Email: `info@mathworks.com`

1.1.5 Technical Support

1.1.5.1 Student Support Policy

Neither Prentice-Hall, Inc. nor The MathWorks, Inc. provides technical support to student users of The Student Edition of SIMULINK.

If you encounter difficulty while using the Student Edition software:

1. Read the relevant tutorial and reference sections of this *User's Guide* containing information on the commands or procedures you are trying to execute.
2. Use the software's online help facility by typing `help simulink` at the MATLAB prompt.
3. Write down the sequence of procedures you were executing so that you can explain the nature of the problem to your instructor. Be certain to note the exact error message you encountered.
4. If you have consulted this *User's Guide* and the online help and are still stymied, you can post your question to the `comp.soft-sys.matlab` newsgroup, if you have access to Usenet newsgroups. Many active SIMULINK users participate in the newsgroup, and they are a good resource for answers or tips about using SIMULINK.

1.1.5.2 Student User Registration

Students who have purchased the software package will find a card in the package for registering as a user of The Student Edition of SIMULINK. Take a moment now to complete and return this card to us. Registered student users:

- Are entitled to replace defective disks at no charge.
- Qualify for a discount on upgrades to professional versions of SIMULINK.
- Receive the *MATLAB News & Notes* quarterly newsletter, with information on new products, technical notes and tips, application articles, a calendar of trade shows and conferences, and other useful information.
- Become active members of the worldwide SIMULINK user community.

1.1.5.3 Defective Disk Replacement

Contact Prentice Hall at (201) 592-3096 for disk replacement. You must send Prentice Hall your damaged or defective disk, and they will provide you with a new one.

1.1.5.4 Limited Warranty

No warranties, express or implied, are made by The MathWorks, Inc. that the program or documentation is free of error. Further, The MathWorks, Inc. does not warrant the program for correctness, accuracy, or fitness for a task. You rely on the results of the program solely at your own risk. The program should not be relied on as the sole basis to solve a problem whose incorrect solution could result in injury to person or property. If the program is employed in such a manner, it is at the user's own risk, and The MathWorks, Inc. disclaims all liability for such misuse. Neither The MathWorks, Inc. nor anyone else who has been involved in the creation, production, or delivery of this program shall be liable for any direct or indirect damages.

1.2 Professional Application Toolboxes

One of the key features of SIMULINK is that it is built atop MATLAB. As a result, SIMULINK users have direct access to the wide range of MATLAB-based tools for generating, analyzing, and optimizing systems implemented in SIMULINK. These tools include MATLAB Application Toolboxes, specialized collections of M-files for working on particular classes of problems.

Toolboxes are more than just collections of useful functions; they represent the efforts of some of the world's top researchers in fields such as controls, signal processing, and system identification. Because of this, the MATLAB Application Toolboxes let you "stand on the shoulders" of world class scientists.

All toolboxes are built using MATLAB. This has some very important implications for you:

- Every toolbox builds on the robust numerics, rock-solid accuracy, and years of experience in MATLAB.
- You get seamless and immediate integration with SIMULINK and any other toolboxes you may own.
- Since all toolboxes are written in MATLAB code, you can take advantage of MATLAB's open-system approach. You can inspect M-files, add to them, or use them for templates when you're creating your own functions.
- Every toolbox is available on any computer platform that runs MATLAB.

The Student Edition of MATLAB contains two toolboxes, bundled free with the software: the Signals and Systems Toolbox and the Symbolic Math Toolbox. These toolboxes are educational versions of the professional Signal Processing Toolbox, Control System Toolbox, and Symbolic Math Toolbox.

Here is a list of professional toolboxes currently available from The MathWorks. This list is by no means static—there are more being created every year.

The Control System Toolbox

The Control System Toolbox, the foundation of the MATLAB control design toolbox family, contains functions for modeling, analyzing, and designing automatic control systems. The application of automatic control grows with each year as sensors and computers get cheaper. As a result, automatic controllers are used not only in highly technical settings for automotive and aerospace systems, computer peripherals, and process control, but also in less obvious applications such as washing machines and cameras.

The Frequency-Domain System Identification Toolbox

The Frequency-Domain System Identification Toolbox by István Kollár, in cooperation with Johan Schoukens and researchers at the Vrije Universiteit in Brussels, is a set of M-files for modeling linear systems based on measurements of the system's frequency response.

The Fuzzy Logic Toolbox

The Fuzzy Logic Toolbox provides a complete set of GUI-based tools for designing, simulating, and analyzing fuzzy inference systems. Fuzzy logic provides an easily understandable, yet powerful way to map an input space to an output space with arbitrary complexity, with rules and relationships specified in natural language. Systems can be simulated in MATLAB or incorporated into a SIMULINK block diagram, with the ability to generate code for standalone execution.

The Higher-Order Spectral Analysis Toolbox

The Higher-Order Spectral Analysis Toolbox, by Jerry Mendel, C. L. (Max) Nikias, and Ananthram Swami, provides tools for signal processing using higher-order spectra. These methods are particularly useful for analyzing signals originating from a nonlinear process or corrupted by non-Gaussian noise.

The Image Processing Toolbox

The Image Processing Toolbox contains tools for image processing and algorithm development. It includes tools for filter design and image restoration; image enhancement; analysis and statistics; color, geometric, and morphological operations; and 2-D transforms.